GEM based TRD

Tonko Ljubicic, Bob Scheetz, Lijuan Ruan, **Zhangbu Xu (BNL)**
Gerard Visser, Indiana University (CEEM)
Cheng Li, Hongfang Chen, Ming Shao (USTC/China)
Dave Underwood, Hal Spinka (ANL)
Subhasis Chattopadhyay (VECC)

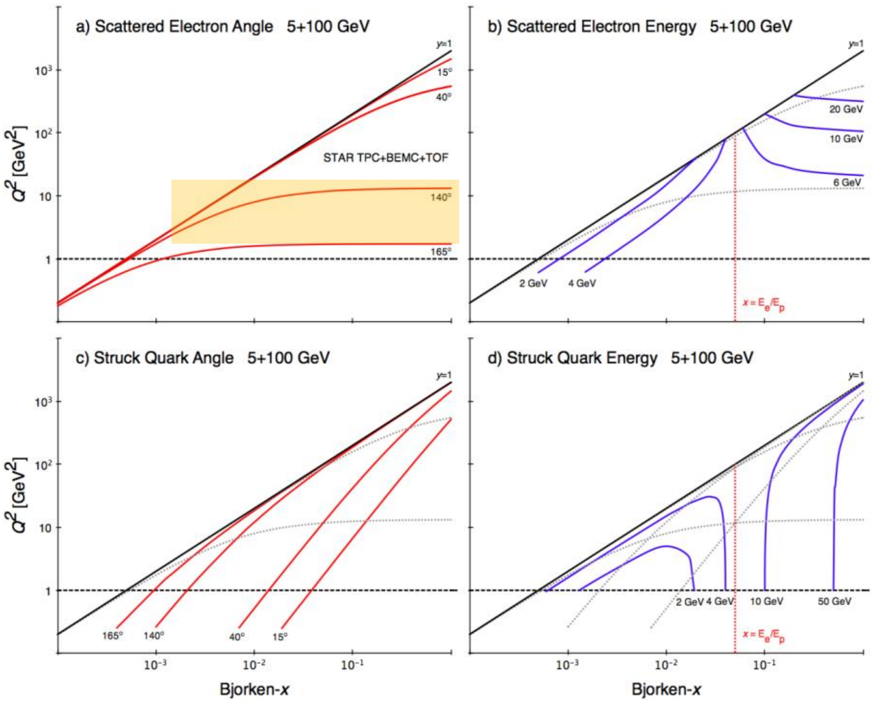
1. Brief review of proposal submitted in 12/2012
2. Addressing Committee Report and recommendations
3. New Developments and Plans

We propose an R&D project to use GEM detector with Xe+CO_2 for detection of transition radiation. The goals are:
a) study the GEM readout performance for dE/dx (TR) signals and its position resolution in the TPC-style readout with 3-4cm ionization chamber;
b) investigate different GEM configuration (regular GEM vs Thick GEM, Ar+CO_2 vs Xe+CO_2) and its impact on tracking and dE/dx.

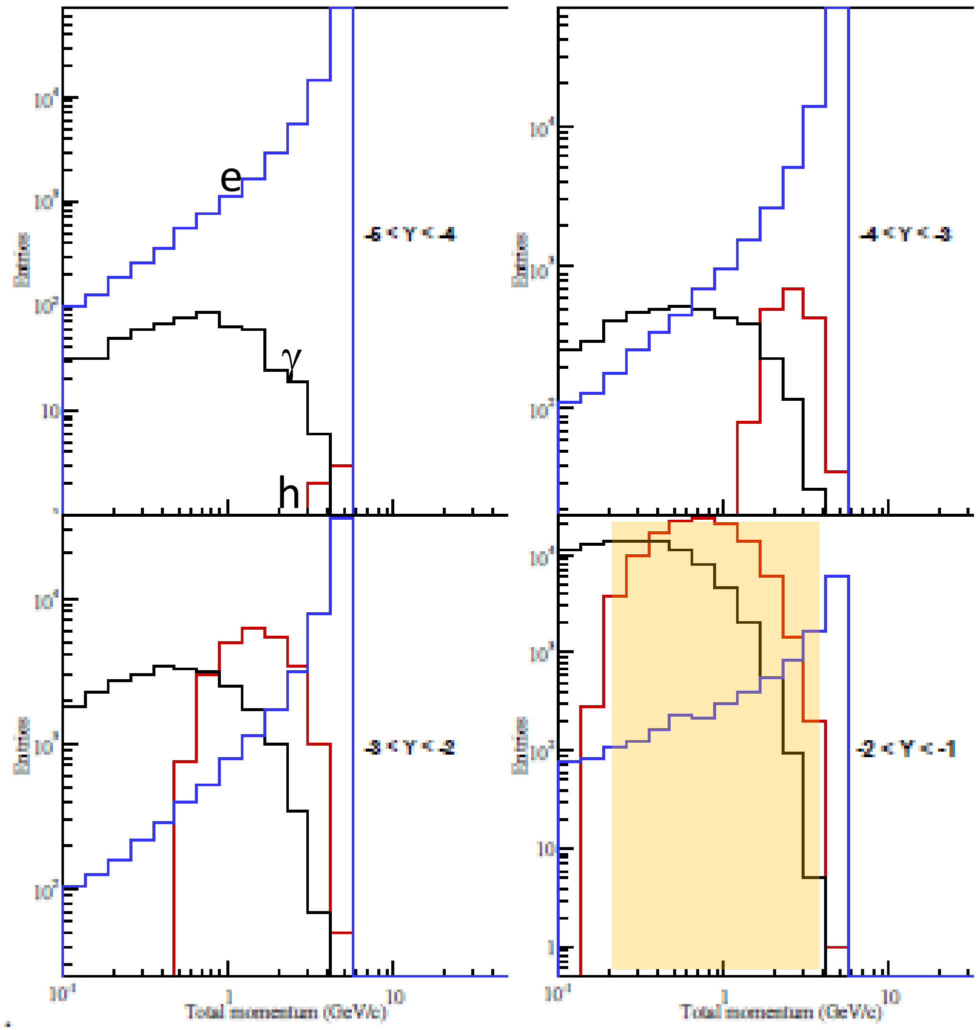
Electron ID in EIC

5x100 ep

Ernst Sichtermann (LBL)

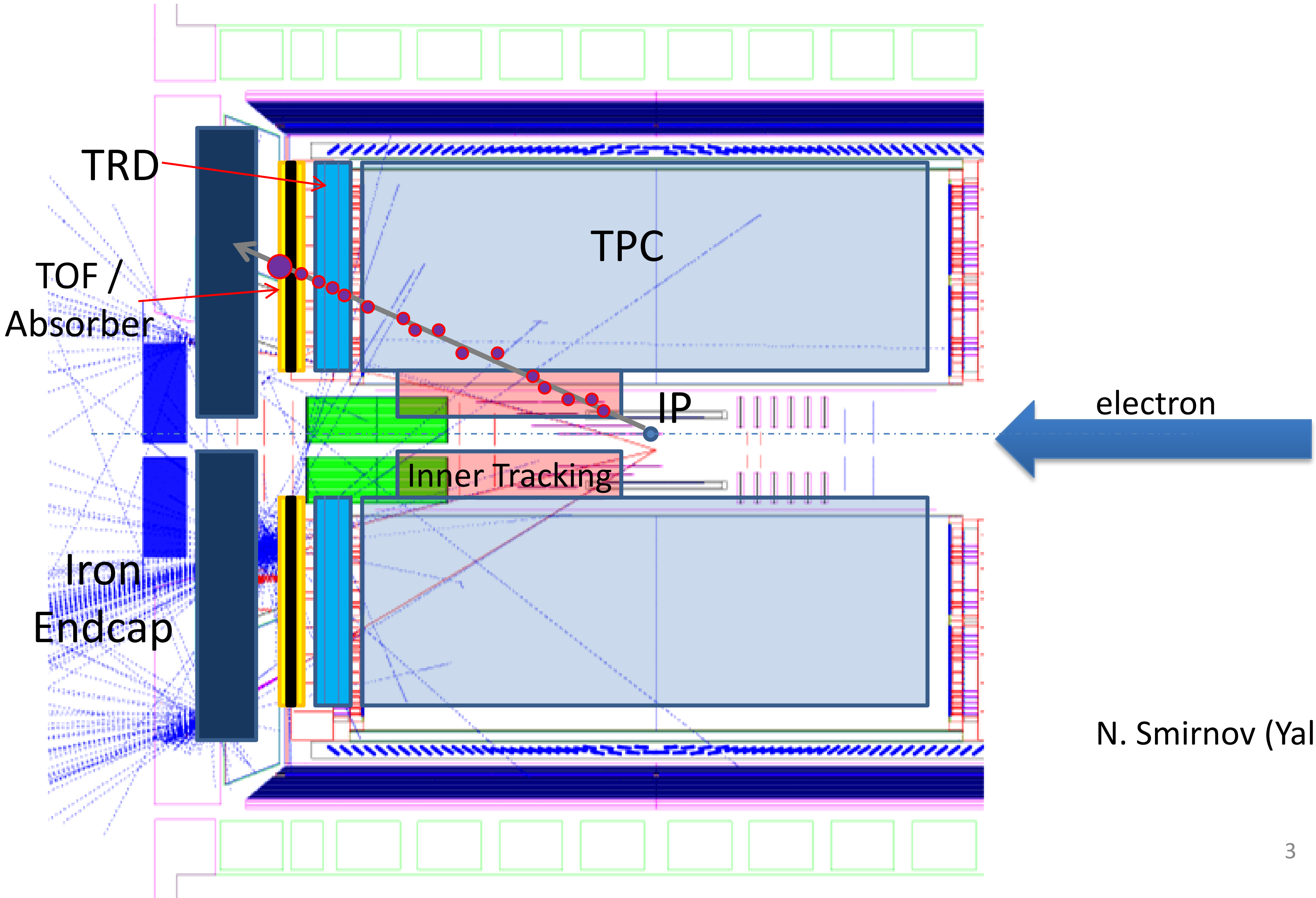


INT report (arXiv:1108.1713) Fig.7.18.



1. Electron coverage: $1>\eta>-2.5$
2. PID e/h: 1000
3. Momentum: $0<p<6$ GeV/c
4. Low material: photon conversion

Conceptual Configuration



N. Smirnov (Yale)

Electron Identification (dE/dx+TOF)

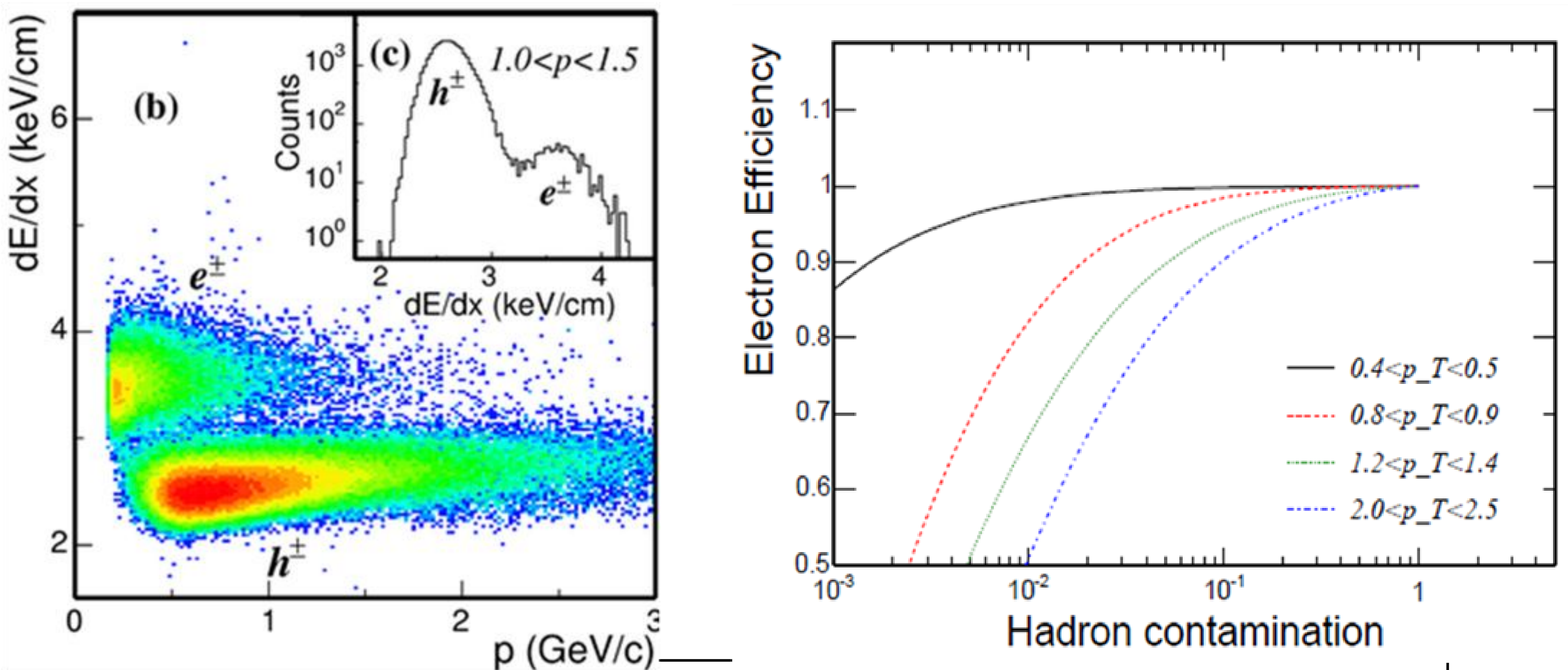
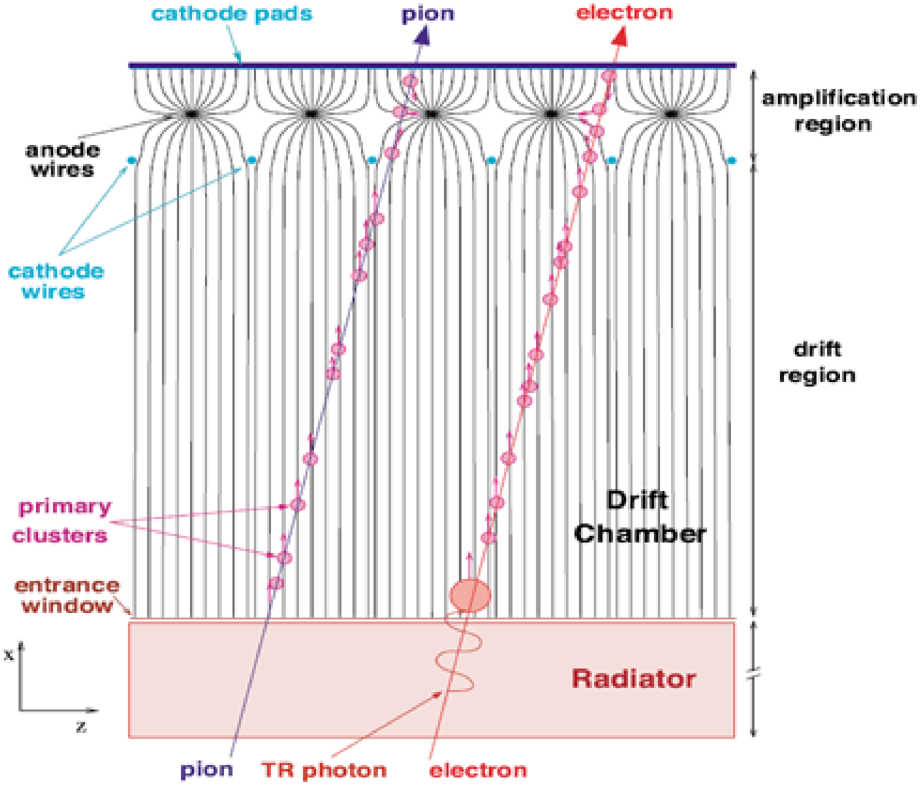
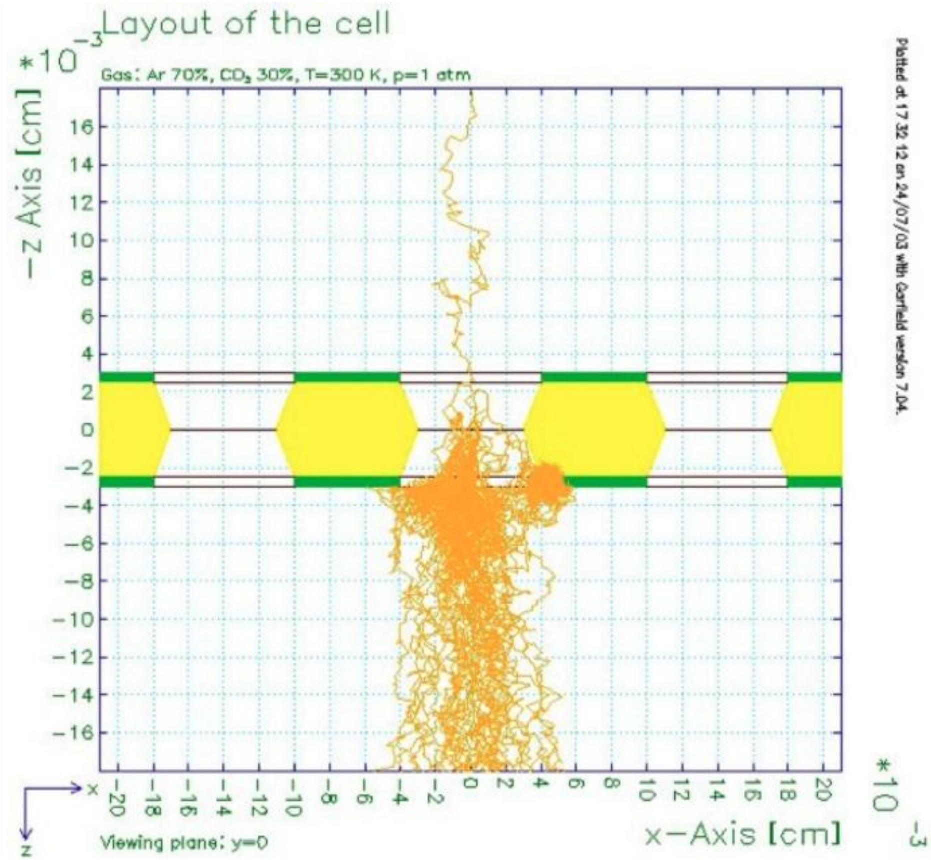


Figure 9. The dE/dx measured by STAR TPC as a function of particle momentum, with velocity cut by TOF, and (right panel) the electron efficiency after dE/dx cut as a function of hadron contamination in different pT range.

Ming Shao (USTC), Xin Dong (LBL)

R&D on GEM based TRD





- dE/dx with Xe+CO_2
- position resolution
- TRD gain

Committee Report and Recommendations (12/2012)

The Committee is interested in the concept of identifying electrons at an EIC via a combination of tracking, TOF and detection of TR photons.

Thank you!!!

ii) The Committee would like to understand better over what range of pseudorapidity a TPC/TR could work, from the standpoint of required momentum resolution, hit areal density and overall hit rate, and whether space charge poses any problems in particular at forward angles.

i) It was not clear whether this technique is proposed to operate in isolation or in conjunction with further detectors such as EM Calorimeters or Cerenkov detectors, or in a different range of pseudorapidity. More generally, the direction of the overall R&D effort and development of detector reference design for an EIC would benefit from an exposition of electron detection strategies to be deployed in various regions and how well they are expected to identify electrons and reject hadrons.

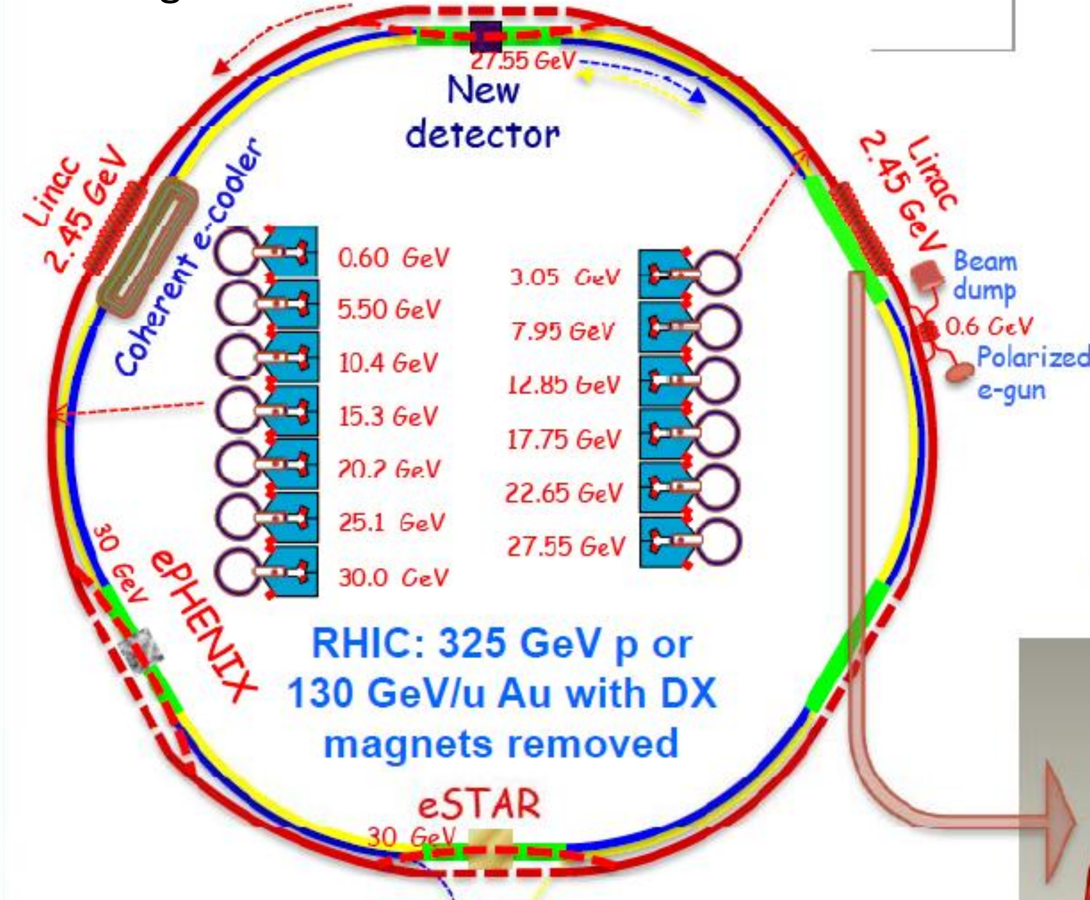
The authors propose to develop a GEM which can operate with Xe in combination with another gas such as CO2, then to measure the position and energy resolution achieved with the GEM, identify and prepare appropriate electronics, and in future years study emission and detection of TR photons.

iii) The Committee encourages the authors to delineate more thoroughly the requirements on the electronics. Such electronics were developed at BNL for the PHENIX Time Expansion Chamber and include a preamp with wide dynamic range coupled to a planar TPC and a non-linear FADC. The FADC combined a linear lower range with a non-linear upper range to accommodate the large difference energy deposition in a unit gas volume between normal ionization by a minimum-ionizing charged particle and a TR photon of keV energy.

iv) A revised proposal should note improvements required beyond the performance achieved above to meet the needs of an EIC.

eRHIC Design Under Active Consideration

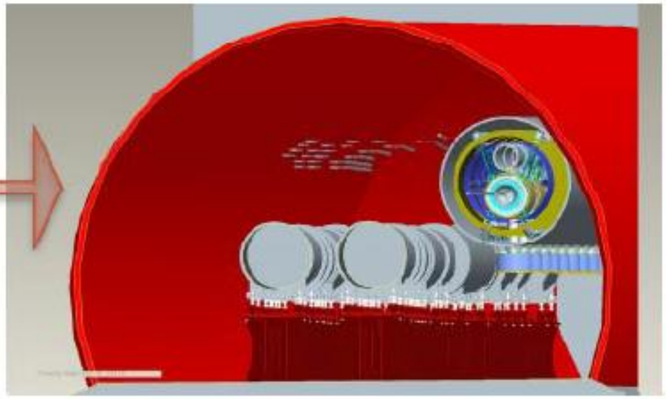
Steve Vigdor: June 2011



✓All-in tunnel staging approach uses two energy recovery linacs and 6 recirculation passes to accelerate the electron beam.

✓Staging: the electron energy will be increased in stages, from 5 to 30 GeV, by increasing the linac lengths .

✓Up to 3 experimental locations

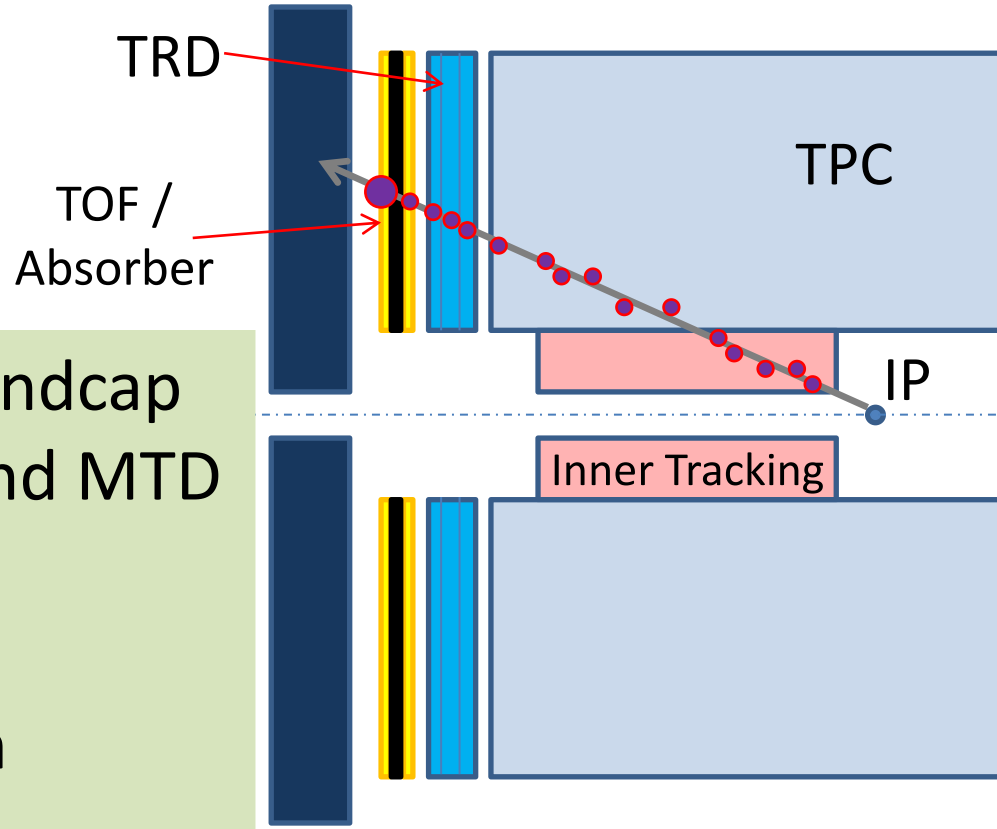


Vis-à-vis earlier MeRHIC design, this allows for:

- *more IP's*
- *reduced cost*
- *reusing infrastructure + det. components for STAR, PHENIX*
- *easier upgrade path from 5 GeV eRHIC-I*
- *minimal environmental impact concerns*
- *IR design to reach 10^{34} luminosity*

TRD+TOF at Endcap ($-2<\eta<-1$)

- Inner tracking
- TPC (endcap region): TRD + TOF/Absorber sandwich



Ming Shao (USTC)

- Within <70cm space inside endcap
- TOF as start-time for BTOF and MTD
- TOF + dE/dx for electron ID
- TOF for hadron PID
- Extend track pathlength with precise points
- High-precision dE/dx (Xe+CO_2) TRD

Similar concept can apply to other detector configuration
The R&D explores the generic features of this concept

A comparison of TRDs

Experiment	Radiator (x,cm)	Detector (x,cm)	Area (m^2)	N	L (cm)	N. chan.	Method	π_{rej}
HELIOS	foils (7)	Xe-C_4H_{10} (1.8)	0.5	8	70	1744	N	2000
H1	foils (9.6)	Xe-He-C_2H_6 (6)	1.8	3	60	1728	FADC	10
NA31	foils (21.7)	Xe-He-CH_4 (5)	4.5	4	96	384	Q	70
ZEUS	fibres (7)	Xe-He-CH_4 (2.2)	3	4	40	2112	FADC	100
D0	foils (6.5)	Xe-CH_4 (2.3)	3.7	3	33	1536	FADC	50
NOMAD	foils (8.3)	Xe-CO_2 (1.6)	8.1	9	150	1584	Q	1000
HERMES	fibres (6.4)	Xe-CH_4 (2.54)	4.7	6	60	3072	Q	1400
kTeV	fibres (12)	Xe-CO_2 (2.9)	4.9	8	144	~10 k	Q	250
PAMELA	fibres (1.5)	Xe-CO_2 (0.4)	0.08	9	28	964	Q,N	50
AMS	fibres (2)	Xe-CO_2 (0.6)	1.5	20	55	5248	Q	1000
PHENIX	fibres (5)	Xe-CH_4 (1.8)	50	6	4	43 k	FADC	~300
ATLAS	fo/fi (0.8)	Xe-CO_2-O_2 (0.4)	31	36	51-108	425 k	N,ToT	100
ALICE	fi/foam (4.8)	Xe-CO_2(3.7)	126	6	52	1.2 mil.	FADC	200

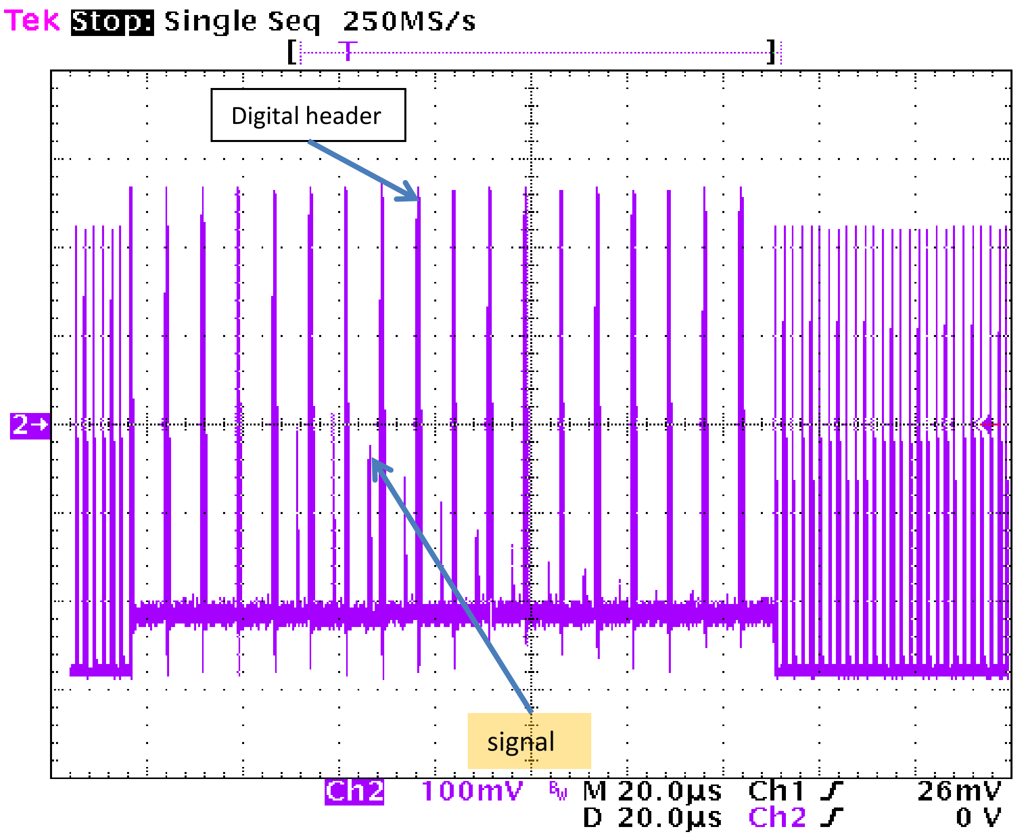
More generically, it seems to be a good idea to develop new TRD (tracking, radiation and low material) for EIC
since electrons are the primary particles in action.
Focus on R&D on TRD prototype for this proposal

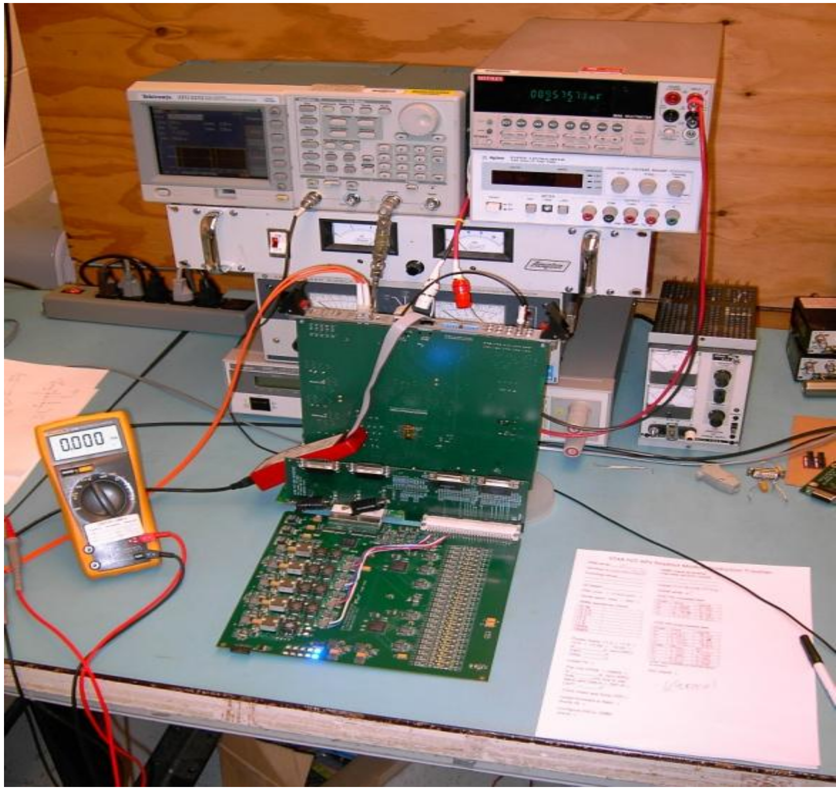
Sending the ALICE prototype from GSI *A. Andronic – ALICE TRD*

Since last EIC R&D Committee Review

- Modify APV system from Forward GEM Tracker (FGT) to readout multiple time bins (Gerard Visser from Indiana University)
- Simulation of momentum resolutions and pile-up estimate from EIC (Ming Shao from USTC/BNL)
- Develop TRD prototype with USTC (Prof. Cheng Li) and IHEP (Dr. Junguang Lu) and (Dave Underwood from ANL)
- In the process of setting up lab (DAQ/Gas/electronics: Tonko Ljubicic and Bob Scheetz at BNL) for GMT (Richard Majka and Nikolai Smirnov from Yale) and TRD test stand at BNL

APV multiple time bins iii)

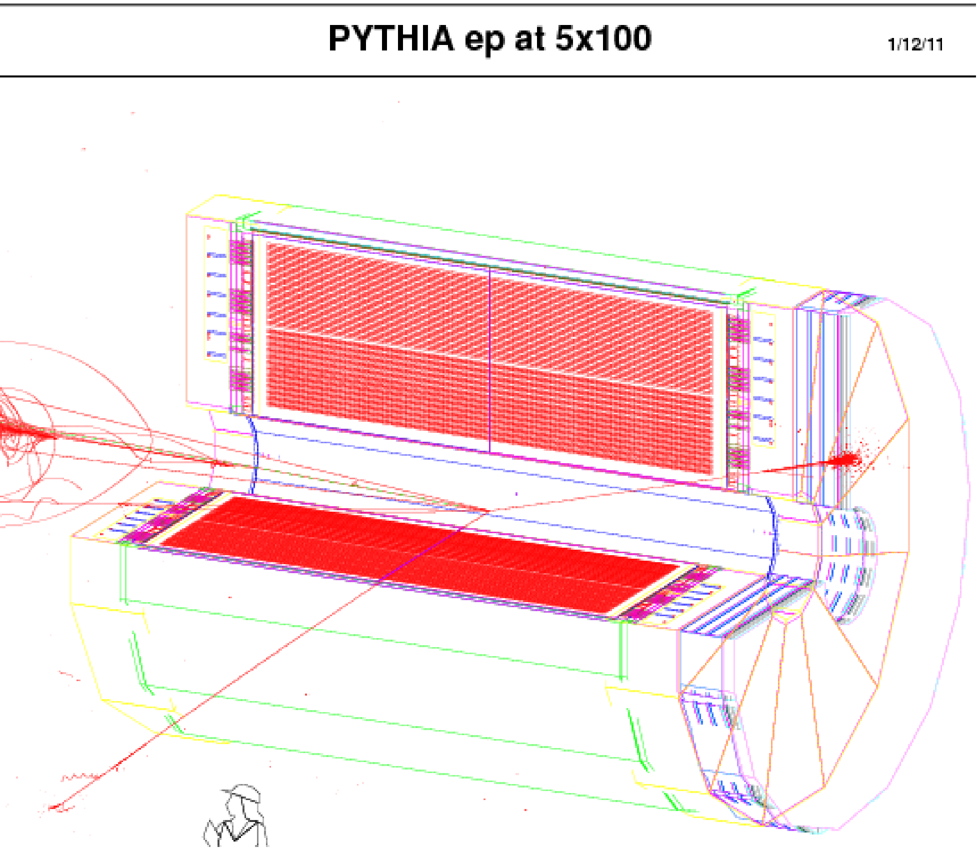


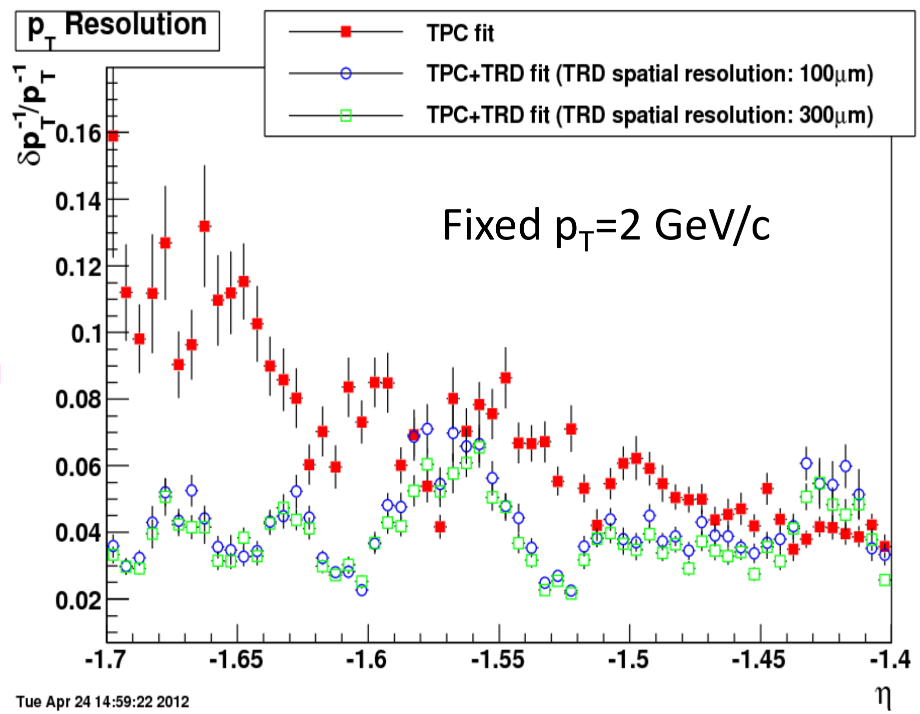


As a ready-to-use electronics for prototype developments;
Future electronics readout would have to be looked into.

For example: 72 Channel 125 MSPS Analog-to-Digital Converter Module for Drift Chamber Readout for the GlueX Detector (G. Visser et al.)

Simulation of momentum resolution ii)





$$\delta k_{res} = \frac{\varepsilon}{L'^2}\sqrt{\frac{720}{N+4}}$$

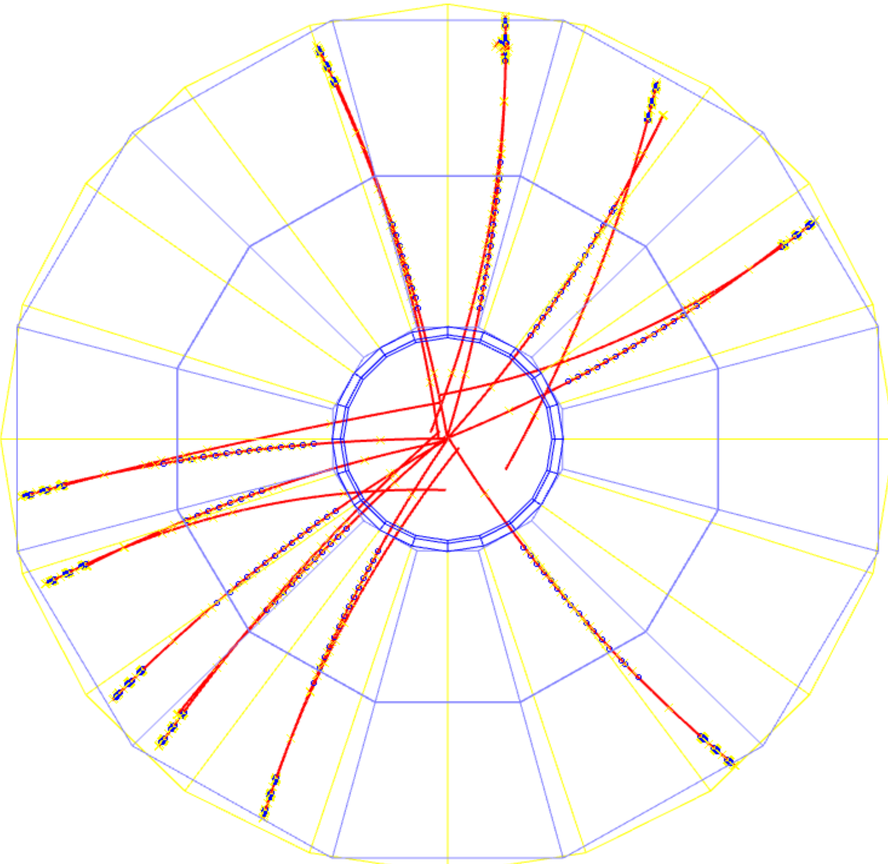
•Require to have good determination of (x,Q^2)
~1--3% momentum resolution (p~= 1GeV/c)
•Low material: multiple scattering, Bremsstrahlung
•Current tracking: perfect helix fit

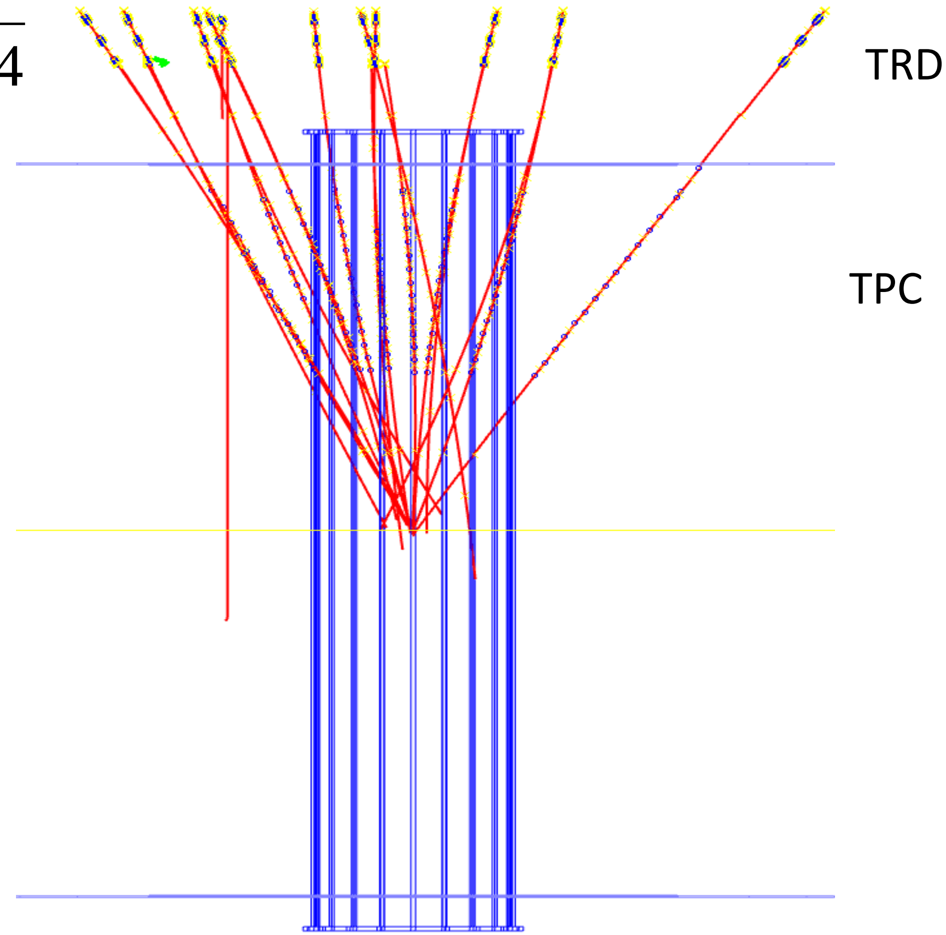
Tracking with Kalman Filter ii)

$\eta \sim -1.2$
$p_T = 1\text{GeV/c}$
10 MC tracks

$$\delta k_{res} = \frac{\varepsilon}{L'^2}\sqrt{\frac{720}{N+4}}$$

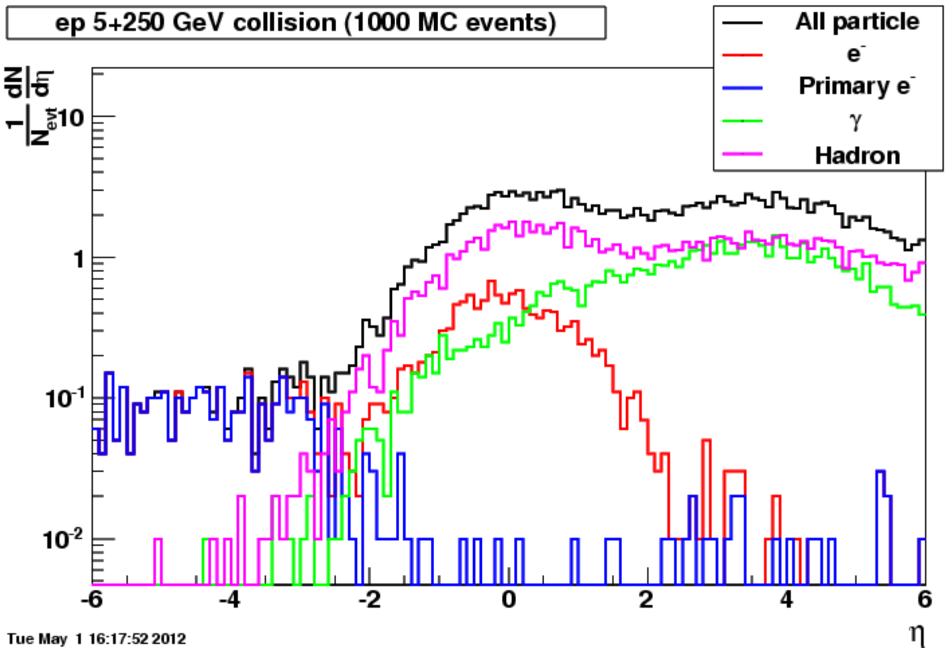
STAR Computing Group: in progress

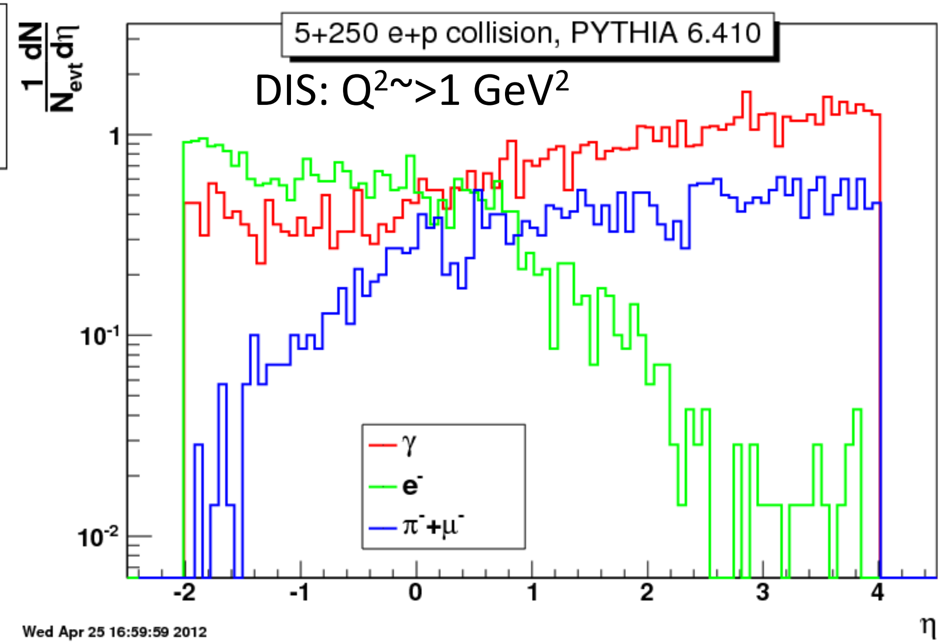




Other upgrades possible improve the tracking resolution:
- Inner TPC Upgrade
- Precision Tracker at $|r|<50\text{cm}$

Occupancy and pile-up ii)





QED α=1/137 and low multiplicity ➔ an order of magnitude lower pile-up than RHIC

Beam species	Sqrt(s)	Peak Luminosity (cm^{-2})	Cross section (cm^2)	Nch/dη	**Track density (dNch/dη MHz)**	Hit density impact hit finding	Space charge impact tracking
e+p	5x250	10^{34}	10^{-28}	0.7	**0.7**		
Au+Au	100x100	5×10^{27}	7×10^{-24}	161	**6**	Minor	Corrected to good precision
p+p	100x100	5×10^{31}	3×10^{-26}	2	**3**	Minor	Corrected to good precision
p+p	250x250	1.5×10^{32}	4×10^{-26}	3	**18**	Significant for inner	Corrected to acceptable

Thin THGEM iv)

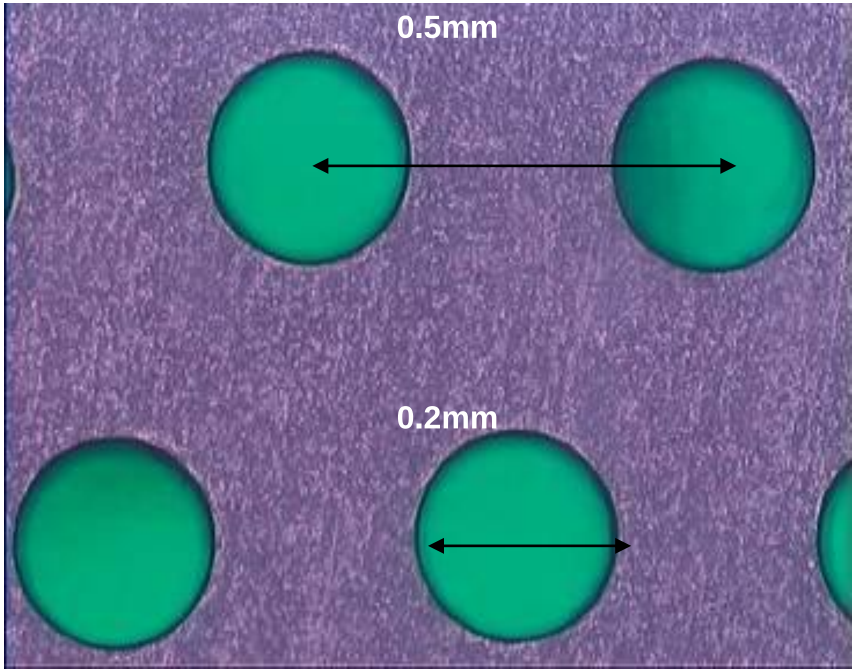
Copper 20μm

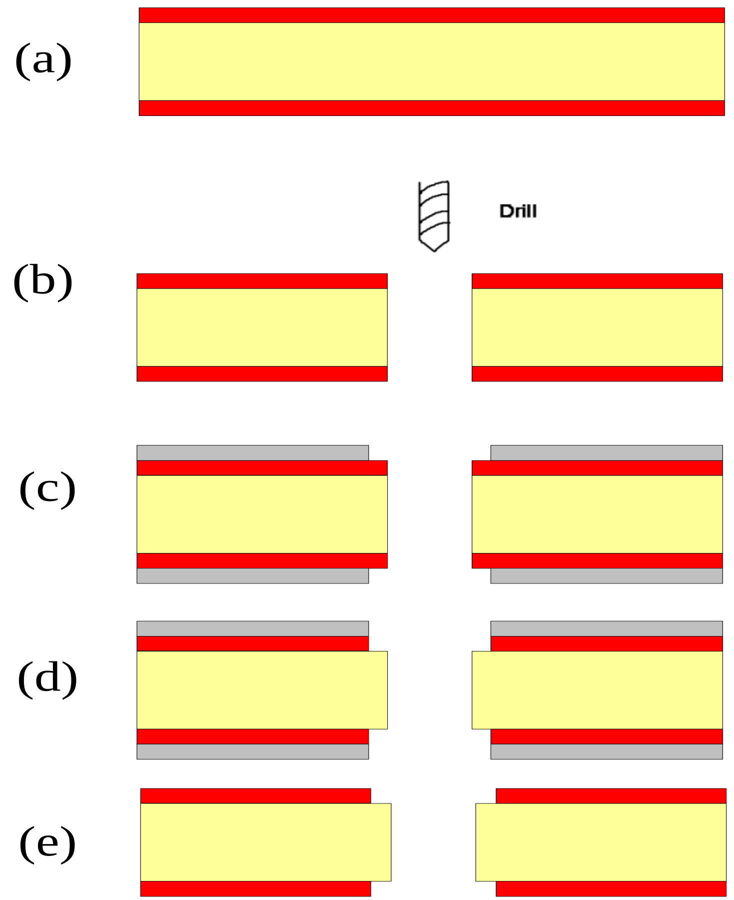
FR4 160μm

Thickness 200μm

Hole 200μm

pitch 500μm





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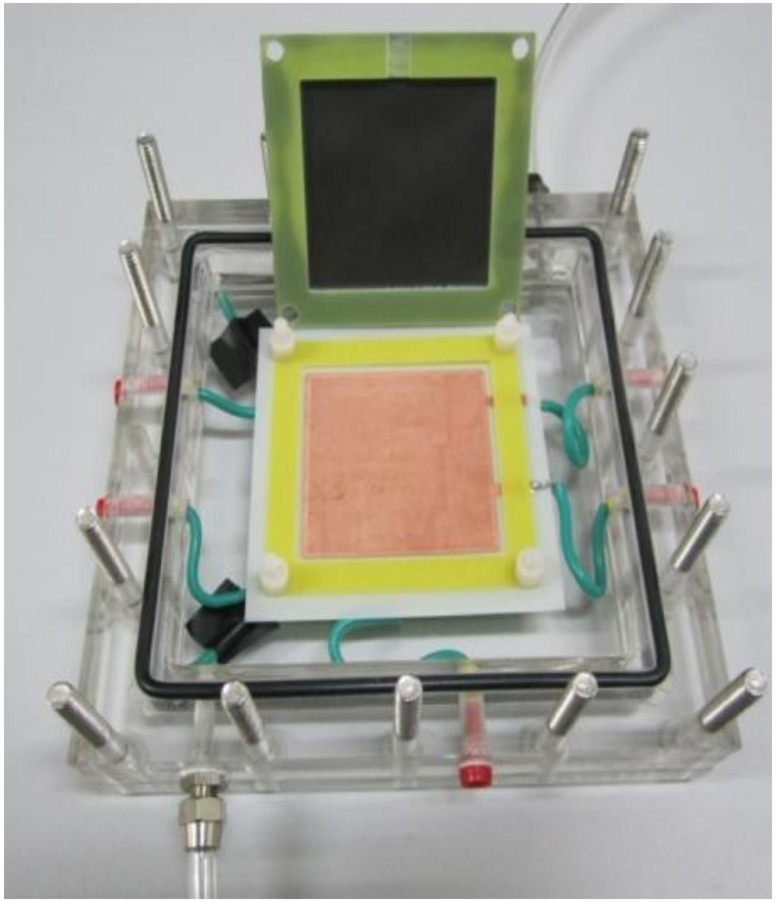
散裂中子源
China Spallation Neutron Source

Prototype Products at IHEP/China



1. Ionization chamber: 6mm
2. Energy Resolution: 16% for ^{55}Fe
   @ Gain = 3700 Ar/iC_4H_{10}(97/3%)
3. Spatial resolution: 0.25mm

Plans

Short-term (summer) goals

- Setup test stand (DAQ/APV/cosmic ray)
- Construct prototype 10x10cm^2 at IHEP (on-going)
- Study properties of the prototype (gain, stability, energy resolution) using (Ar+CO2)
- Read multiple time bins and construct tracklets
- Change gas to Xe+CO_2

FY 2013 year project plan

- Add radiators
- Benchmark performance with ALICE prototype module (obtained from GSI)
- Characterize TR photon yields
- Test Beam
- Compute electron identification power
- (maybe) larger prototype

International collaboration on developing new GEMTRD detector prototype for EIC
We are excited about the opportunity and hope the committee does too!

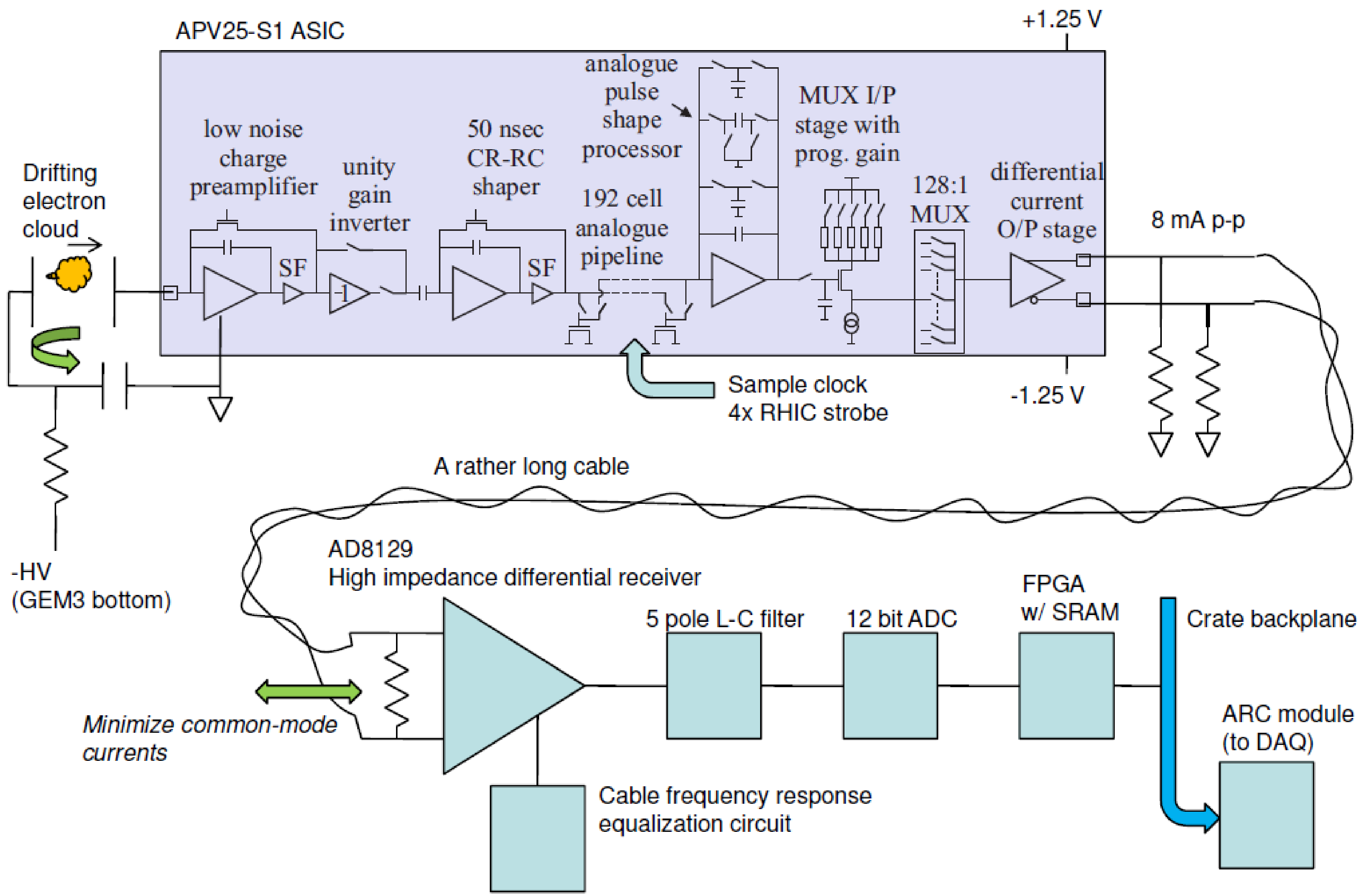
Backup slides

Name	Institute	responsibilities
Zhangbu Xu (Co-PI)	BNL	Organizing the collaboration (phone meeting, tasks); construct prototype
Ming Shao (Co-PI)	USTC, Sabbatical leave at BNL (07/11—07/12)	Initial GEANT4 detector simulation; construct prototype;
Cheng Li	USTC	Prototype construction, testing at BNL; Possible future beam test; Detector expert on TOF/GEM R&D
Tonko Ljubicic	BNL	DAQ and integrating electronics readout
Gerard Visser	Indiana University	Modify FGT electronics for TRD R&D
Bob Scheetz	BNL	GEM Pad plane design and interface
Richard Majka	Yale	GEM Pad plane design and interface; Mainly in connection with GMT project.
Student	One from USTC or VECC stations at BNL	Carry out simulation and participate in prototype construction Data analysis from cosmic ray/beam test
	VECC and USTC	Independent funds on large-area GEM (not part of this proposal); request some supports for travel and material for EIC related activities
Dave Underwood	ANL	Develop Thick GEM and expert on GEM Electronics.

Item	Description	Fund FY12 (K$)	FY13
Detector material/DAQ	Detector components, computer, gas, test beam	8.3+10+10=28.3	
Engineer	Electronics and mechanics design	15.4	9
2 students (VECC and USTC)	Two students associated with the professors in both institutes for GEM related R&D and simulations	12	50
Travel/test beam	Collaboration and meetings	10	20
International collaboration	Joint effort with prototype tests/material and simulations by international collaborators	10	10
Total		75.7	89

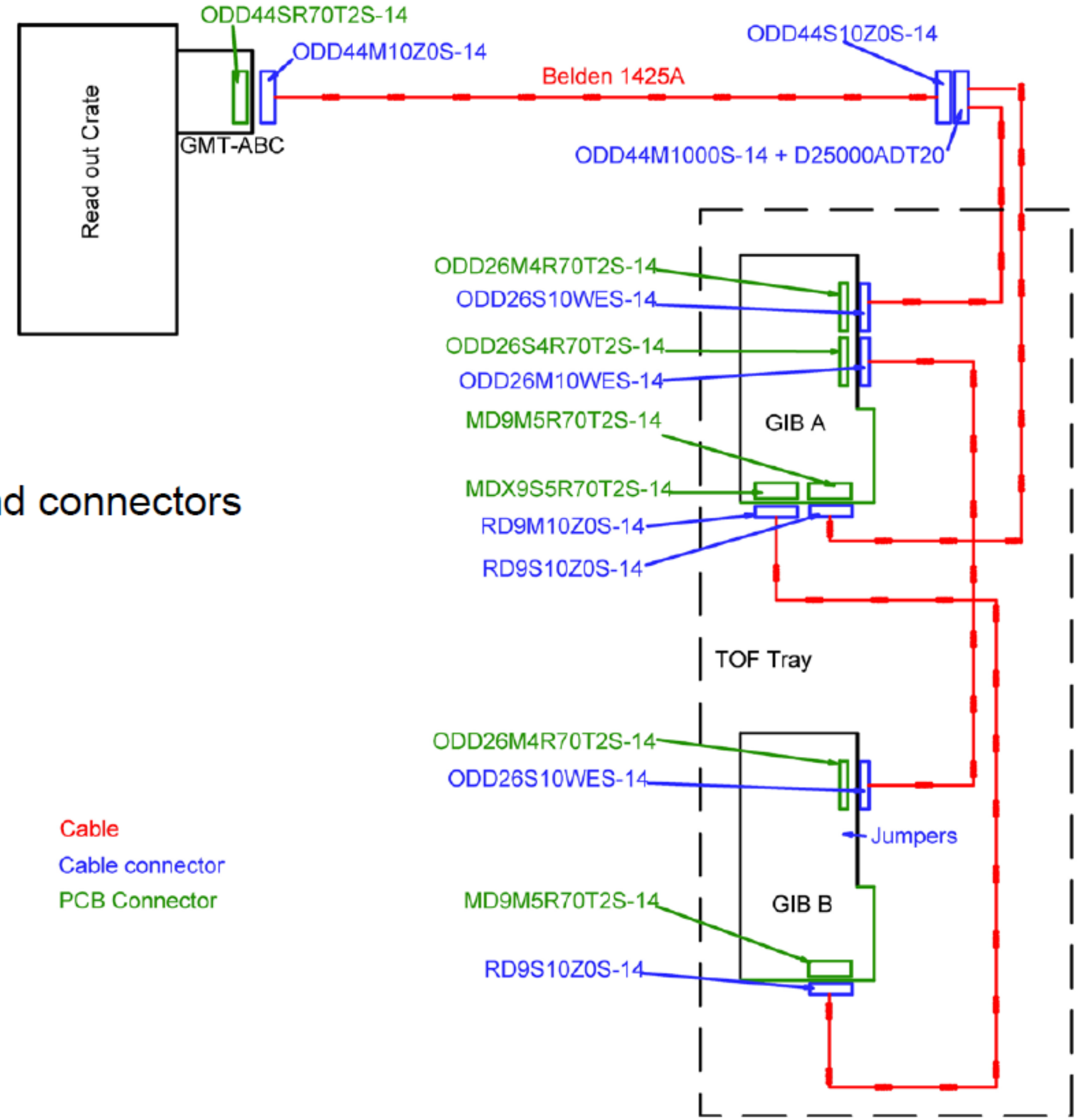
Separate/parallel funding (FY14) can be applied to Chinese funding agencies by our collaborators after initial successful R&D (summer 2012).

Review of the readout signal path

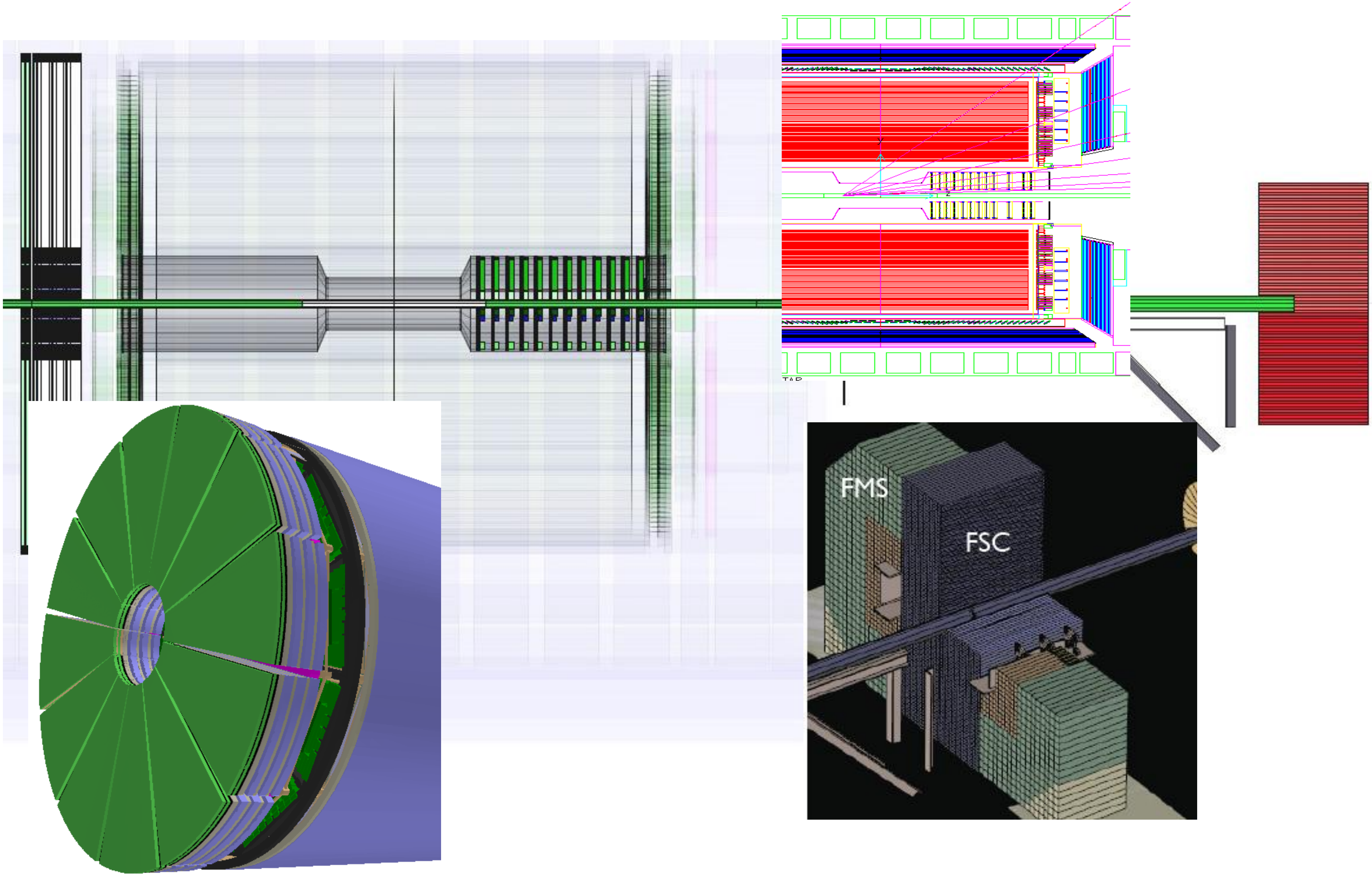


Cables and connectors to be used for TRD

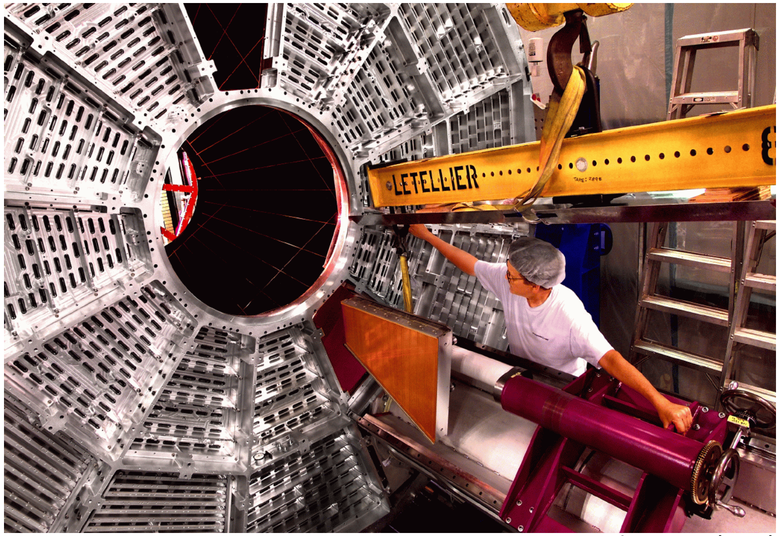
GMT connections and connectors



Simulation Geometry



STAR Inner TPC Sector Upgrade



Jim Thomas (LBL)

Physics and Instrumentation R&D

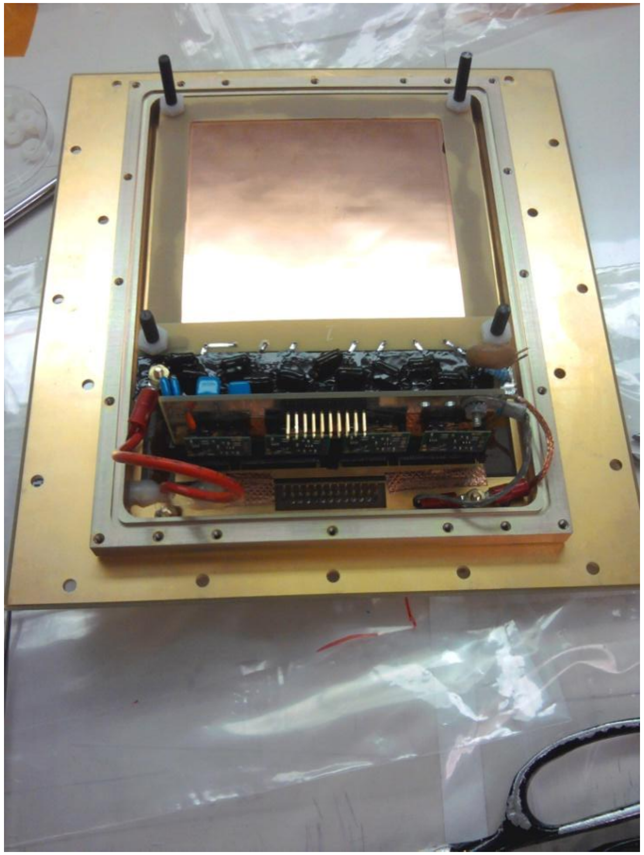
- Optimize number of rows to match available funds & Eng. factors
- Optimize pad size for greatest physics return
- Join existing R&D efforts for PASA and Altro chips

Technical Challenges (R&D by another name)

- Pad plane design – traces & connector technology, alignment
- Winding large wire planes … an art rather than a science
- Factory – assembly line, QA and efficiency

GMT

GMT Open Chamber



GMT APV Chip